PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Towards Understanding Healthy and Supportive Acoustic Environments: the case of a nursing home

Paul DEVOS[1]; Pieter THOMAS[1]; Francesco ALETTA[3]; Tara VANDER MYNSBRUGGE[2]; Patricia DE VRIENDT[1-2]; Dominique VAN DE VELDE[1-2]; Dick BOTTELDOOREN[1]

[1] Ghent University, Belgium

[2] Artevelde University College, Belgium

[3] University College London, UK

ABSTRACT

In elderly care a nursing home is a facility where on a residential basis different caring functions are taking place in order to satisfy the specific care needs of the residents. As in many outdoor and indoor situations, the soundscape of such a space, as originated form its acoustic environment, is of crucial importance since it has the potential to affect the behaviour of the residents. Apart from sounds originating from the care-related interactions between staff members and residents and other typical indoor sound sources like equipment noise, a major contribution to the acoustic environment in a nursing home can be the shouting of residents themselves. It is known that in case of residents with dementia, shouting behaviour can be a prevalent element of BPSD (behavioural and psychological symptoms of dementia). Considering the supportive potential of a soundscape, its quality needs to be studied in view of these shouting events. Using signal processing techniques applied to datasets obtained in different nursing homes in Flanders these shouting events can be detected and allow to describe the shouting behaviour of a resident, the temporal pattern of which and its relation to the present soundscape is explored in this paper.

Keywords: Soundscape, dementia, BPSD, supportive acoustics

1. INTRODUCTION

Ageing is a demographic characteristic of our current society and raises a key challenge in worldwide care. As cognitive impairment is a common problem for older people, it leads to difficulties in their functioning. In case of dementia, this impairment can lead to problematic behaviour, which symptoms are known as BPSD (Behavioural and Psychological Symptoms of Dementia). Since dementia or dementia symptoms can be observed in more than three-quarters of the residents of nursing homes (1) it gives rise to a higher level of work related stress for nursing staff and a lower quality of life for residents. Among the different symptoms the agitated and unattended (and often repeated) shouting is a specific type of behaviour disturbing the stay of other residents and making the work of nursing staff unattractive.

With the definition of a soundscape (2) a construct is available to account for the perception of an acoustical environment as perceived by a person or a group of persons in a specific context. Since a nursing home is a specific indoor context, the perceived characteristics can reveal their degree of pleasantness and eventfulness (3). In this way soundscapes in some living homes of nursing homes have been shown to have a rather monotonous and uneventful nature (4).

Soundscapes composed of specific acoustic stimuli (e.g. natural sounds) can contribute to a more positive perception of the environment and can support the feeling and functioning of a person. Such a user was illustrated in (5) where composed continuous daylong soundscapes were delivered to residents present in the living rooms or the individual rooms of nursing homes. Such a supportive intervention arose from co-creation sessions with staff members and related stakeholders to obtain a broadly accepted composition.

Considering the acoustic environment, the group of residents showing a disturbing shouting behaviour needs special attention. Due to the cognitive impairment the shouting of a resident can arise as a reaction to external auditive of visual signals, which sensing is disturbed, or which interpretation lacks agreement with the current context (6, 7). As a consequence these shouting events can be considered as an indicator of stressful periods or moments of disturbance as experienced by the resident.

For this reason our aim is to study the occurrence of these events. In the present study we restrict ourselves to the individual room of a resident in order to have a clear indication of the behaviour of the resident and to explore the daily pattern of these shouting events.

2. METHODS

2.1 Dataset

In order to study the acoustic environment a resident is experiencing cost-effective acoustic sensor nodes were placed in the individual rooms of different residents at places with reasonable distance from specific sources which could bias the results (e.g. television, radio). The sensor nodes were connected to a central server to guarantee operation and were equipped with a storage device to allow continuous long-time sound recording (16 bits, 48 kHz uncompressed sampling). These sound datasets were obtained during the AcustiCare project (8) where the acoustic environment and the soundscape characteristics were studied in 5 different nursing homes in Flanders, Belgium (9-12).

2.2 Shouting event detection

In order to study the shouting events the sound recordings were used to obtain a shouting event detector. In the current stage of our work a standard neural network was constructed for this purpose (13, 14). The general methodology to obtain such a network is depicted in figure 1. In the construction part of this approach training sounds are transferred into a feature set, and on these same training sounds manual annotation is performed to obtain the corresponding annotation set. These are used in a learning engine where in case of a standard neural network forward and backward propagation methods are used to obtain the coefficients of a single hidden layer network. In order to perform the training itself the training set is divided in a training and testing set to obtain a performing acoustic model. This model is the used in the recognition use when input sounds are processed to obtain the output shout annotations. In this way a shouting event detector is obtained.

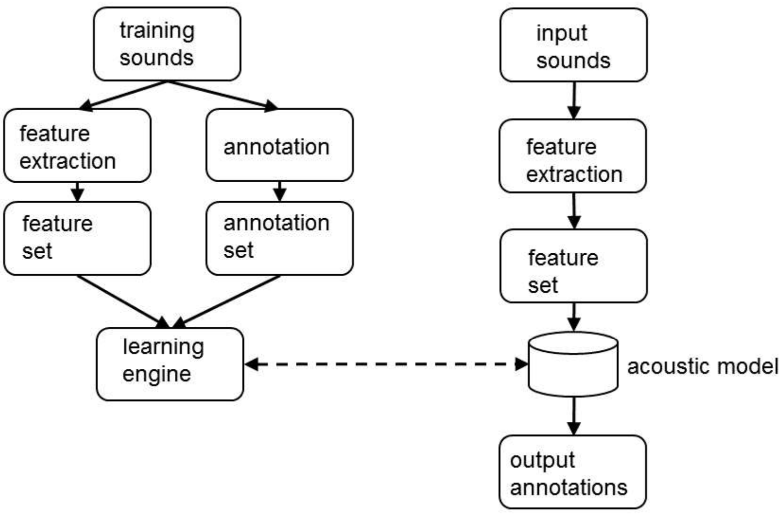

Figure 1 – Framework for construction (left) and recognition use (right) of the neural network based shouting event detector.

3. RESULTS

3.1 Shouting characteristics

Unattended shouting is a common sound of specific residents in a nursing home. In general these sounds (‘shouts’ or ‘screams’, here referred to as shouts) originate from the human vocal tract and their resulting spectrogram structure ranges between a harmonic structure (resulting from almost periodic vocal-fold vibrations) to a noise like structure (resulting from completely atonal turbulent air flow) (15). In order to illustrate such a sound a spectrogram of such a recording is shown in figure 2. In the shouting events the harmonic structure is visible, and in general they show a broad frequency bandwidth, extending up to frequencies in the range of 6000-8000 Hz.

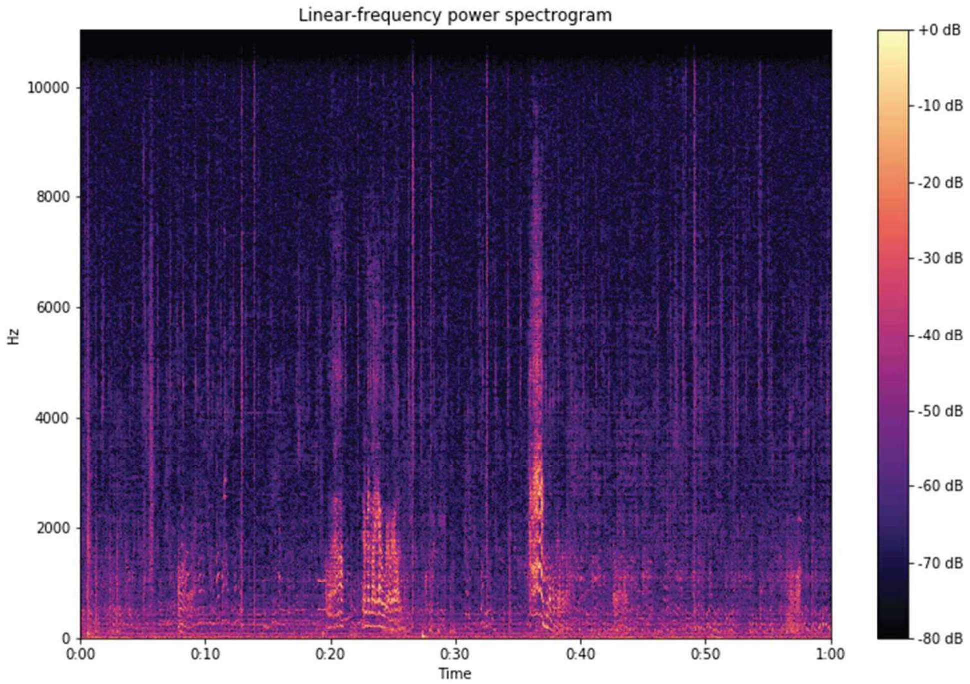

Figure 2 – Example spectrogram of a shouting recording, where time is indicated in seconds. Illustrated is a 60 s recording with different shouting events (around 20 – 26 s and around 36-37 s). (Other sound elements in this spectrogram arise from a background radio and an alarm clock giving a tap every second.)

3.2 Acoustic shouting detection model

In order to build the acoustic model features need to be calculated from the time sliced audio recordings. Non overlapping time slices of 170.67 ms were processed with this purpose to obtain a feature vector containing the following different features subsets: general statistical features (crest factor, standard deviation, variance, mean frequency, median frequency and root mean square value), MFCC coefficients (as is common in audio processing) and the logarithm of filter bank energies (FBE) (16-18). As a preprocessing step a high pass Butterworth (order 8) filter with a cutoff frequency of 500 Hz was used. The 12 MFCC and the 12 FBE coefficients were calculated for frequencies up to 4000 Hz. The chosen frame length was motivated by the observed duration of the shouting events, which show a rather slow temporal sequencing. In addition it has the function to smear out the underlying effect of elementary sounds (as the tapping of an alarm clock) on the feature vectors.

Starting from a manual labelled set of shouting and non-shouting events (with a size of more than 1000 frames) a single hidden layer neural network with 15 hidden nodes was constructed using a 50% split of training and testing sounds. The accuracy obtained for this binary classification achieved a value of 0.98 for the weighted averages f1-score. The model was the used to obtain the timing of the shouting events during a complete day. The resulting shouting index (count of shouting frames during the reference period) of 24 hours of recording in the individual room of a resident is shown in figure 3.

Runs on the datasets of other days showed similar results.

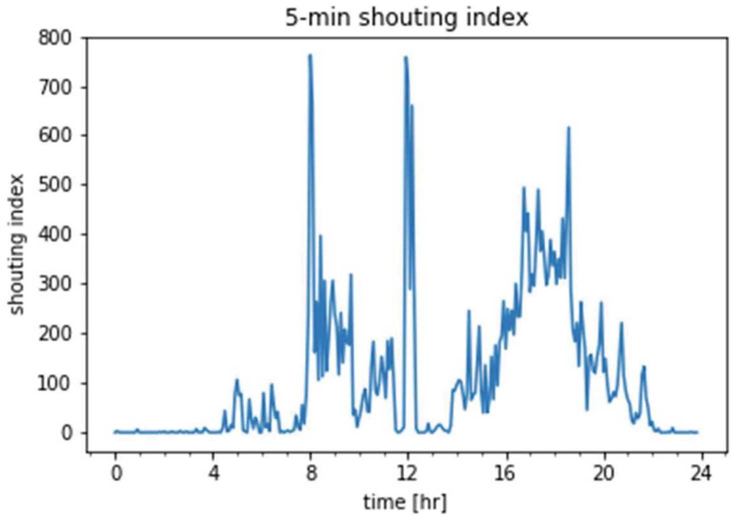

Figure 3 – Shouting index during a complete day (24 hours) as obtained from the acoustic shouting detector from the individual room of a resident in a nursing home.

4. DISCUSSION

4.1 Detector performance

While the current shouting detector was targeted to make a distinction between shouting and non-shouting events (sounds), a degree in shouting exists among these detected sound elements. Such sounds, variants of human vocalizations, can range from breathing sounds, sounds of speaking, chattering to screaming, shrieking and other types of related vocalizations.

Where the feature vector consisted of different subsets of features, it can be assumed that only a limited number of features (e.g. the FBE coefficients) can result in acceptable classification between shouting and non-shouting events. This would result in an improved processing speed.

4.2 Daily temporal pattern

As can be seen from the typical result as presented in figure 3, the shouting index shows clear peaks at distinct moments during the day. A strong peak is present around 8 hr and around 12 hr. These peaks correspond with the time care interventions are taking place. In the morning, the washing of the resident and the breakfast are moments of strong interaction between the resident and the staff, typically giving rise to a high level of shouting. The same occurs at noon when lunch is distributed and the eating is supported by the nursing staff. In the afternoon a broader peak is present. In general dinner takes place around 17 hr and residents are prepared to sleep later in the afternoon. These are also moments with staff intervention and are reflected in the typical resulting graph. The broad peak in the afternoon can arise from afternoon activities taking place which are not understood by the resident. As can be seen shouting is absent during night, but can start already early in the morning, probably reflecting wakening of the resident.

It is clear that the soundscape, reflecting the typical characteristics of the context (in our case the context of a nursing home), is the result of the contextual details of the present situation. The social interactions, in our case the professional care interactions, are an important component to describe the soundscape. Since these interactions are following a specific time schedule, they result in timing indications for delivery of restorative soundscape elements.

5. CONCLUSIONS

In order to study the shouting behaviour of residents of a nursing home showing BPSD standard signal processing methodologies can be used. Long time recordings in individual rooms of such residents were analyzed with this purpose. Based on a feature representation of sound time slices a neural network based acoustic shouting detector was constructed. The degree of shouting over time as referenced by a shouting index (number of shouting frames in a reference period) can be determined in this way, and leads to the temporal pattern of the shouting. As such, this in an indication of the stress or unsafety level the resident is experiencing during a day. During care interactions with care staff takes place, which can involve manipulations disturbing a relaxed feeling of a resident. These have been indicated to give rise to a high shouting level. The temporal pattern reveals important additional information for composing a soundscape, as it can be used as a time directive for the delivery of specific soundscape elements with an overall restorative purpose.

ACKNOWLEDGEMENTS

The dataset used in this study was obtained during the AcustiCare project, which was supported by the Flemish Agency for Innovation and Entrepreneurship (VLAIO) under the TETRA program for applied research (grant no. HBC.2016.0089).

REFERENCES

1. Rebecca Whear, Jo Thompson Coon, Alison Bethel, Rebecca Abbott, Ken Stein, Ruth Garside (2014). What Is the Impact of Using Outdoor Spaces Such as Gardens on the Physical and Mental Well-Being of Those With Dementia? A Systematic Review of Quantitative and Qualitative Evidence. JAMDA 15 (2014) 697e705,
2. International Organization for Standardization. (2014). ISO 12913-1:2014 Acoustics — Soundscape — Part 1: Definition and conceptual framework. Geneva: ISO.
3. Axelsson, Ö., Nilsson, M., & Berglund, B. (2010). A principal components model of soundscape perception. Journal of the Acoustical Society of America, 128 (5), 2836-2846.
4. Aletta, F., Vander Mynsbrugge, T., Van de Velde, D., De Vriendt, P., Thomas, P., Filipan, K., . . . Devos, P. (2018). Awareness of 'sound' in nursing homes: A large-scale soundscape survey in Flanders (Belgium). Building Acoustics, 25(1), 43-59. doi:https://doi.org/10.1177/1351010X17748113
5. Devos, P., Aletta, F., Thomas, P., Filipan, K., Petrovic, M., Botteldooren, D., Vander Mynsbrugge, T., Van de Velde, D. & De Vriendt, P. (2018). Soundscape design for management of behavorial disorders : a pilot study among nursing home residents with dementia. Impact of noise control engineering : proceedings of Inter-Noise 2018.
6. van den Bosch, K. A., Andringa, T. C., Başkent, D., & Vlaskamp, C. (2016). The Role of Sound in Residential Facilities for People With Profound Intellectual and Multiple Disabilities. Journal of Policy and Practice in Intellectual Disabilities, 13(1), 61-68.
7. van den Bosch, K. A., Andringa, T. C., Peterson, W., Ruijssenaars, W. A., & Vlaskamp, C. (2016). A comparison of natural and non-natural soundscapes on people with severe or profound intellectual and multiple disabilities. Journal of Intellectual and Developmental Disability. doi:http://dx.doi.org/10.3109/13668250.2016.1250251
8. www.acusticare.be
9. Aletta, F., Vander Mynsbrugge, T., Thomas, P., Filipan, K., Botteldooren, D., Petrovic, M., . . . Devos, P. (2018). The relationship between noise sensitivity and soundscape appraisal of care professionals in their work environment: a case study in Nursing Homes in Flanders, Belgium. Proceedings of the Euronoise 2018 Conference. Heraklion.
10. Aletta, F., Botteldooren, D., Thomas, P., Vander Mynsbrugge, T., De Vriendt, P., Van De Velde, D., & Devos, P. (2017). Exploring the soundscape quality of five nursing homes in Flanders (Belgium): preliminary results from the AcustiCare project. Proceedings of the Internoise 2017 Conference. Hong Kong.

11.Aletta, F., Botteldooren, D., Thomas, P., Vander Mynsbrugge, T., De Vriendt, P., Van de Velde, D., & Devos, P. (2017). Monitoring Sound Levels and Soundscape Quality in the Living Rooms of Nursing Homes: A Case Study in Flanders (Belgium). Applied Sciences, 7(9), 874. doi:doi:10.3390/app7090874
12. Thomas, P., Aletta, F., Filipan, K., Vander Mynsbrugge, T., De Geetere, L., Dijckmans, A., . . . Devos, P. (2018). Evaluation and improvement of the acoustic comfort in nursing homes: a case study in Flanders, Belgium. Proceedings of the Euronoise 2018 Conference. Heraklion.
13. Chris M. Bishop C.M. (1994). Neural networks and their applications. Review of Scientific Instruments 1994 65:6, 1803-1832
14. Haykin, S. (1994). Neural Networks: A Comprehensive Foundation. Prentice Hall PTR Upper Saddle River, NJ, USA
15. Tokuda, I., Riede, T., Neubauer, J., Owren, MJ., Herzel, H. (2002). Nonlinear analysis of irregular animal vocalizations. J Acoust Soc Am. 2002 Jun;111(6):2908-19.
16. Zhang, Chi, and John HL Hansen (2007). Analysis and classification of speech mode: whispered through shouted. INTERSPEECH, pp. 2289-2292. 2007.
17. Weimin Huang, Tuan-Kiang Chiew, Haizhou Li, Tian Shiang Kok, Biswas, J. (2010). Scream detection for home applications. Industrial Electronics and Applications (ICIEA), 2010 the 5th IEEE Conference on , pp.2115-2120, 15-17 June 2010.
18. Wen-Hung Liao, Yu-Kai Lin (2009). Classification of non-speech human sounds: Feature selection and snoring sound analysis. Systems, Man and Cybernetics, 2009. SMC 2009. IEEE International Conference on, pp.2695-2700, 11-14 Oct. 2009.

Proceedings of the

ICA 2019 AND EAA EUROREGIO

23rd International Congress on Acoustics, integrating 4th EAA Euroregio 2019

9 - 13 September 2019, Aachen, Germany

ISSN 2226-7808 and 2415-1599
ISBN 978-3-939296-15-7